HOW ASTRONOMERS USE THE ELECTROMAGNETIC SPECTRUM

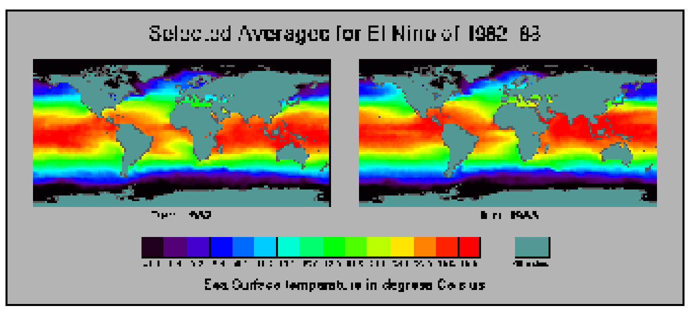
The development of instruments to measure w avelengths of light in all parts of the Electromagnetic Spectrum has contributed immensely to science.

We now know that certain animals snakes) can "see" infrared light. This allow s them to find prey in the dark because thermal energy is emitted in the infrared. Scientists have developed cameras that allow us to "see" infrared light. Below is an infrared image of an engineer holding a burning match.

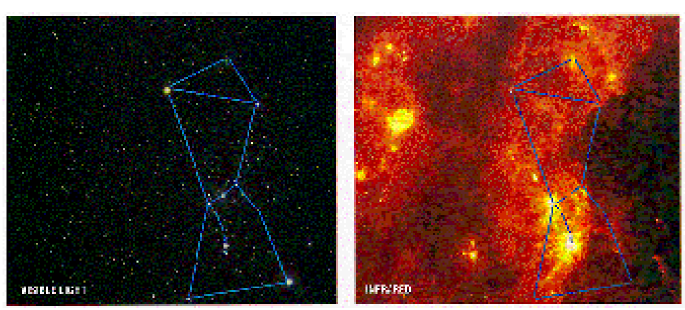
Photo to right: Courtesy of Infrared Information Processing Center, California Institute of Technology, Jet Propulsion Laboratory

"False colors" have been used to indicate temperature. Note the w hite and deep red in the flame and the engineer's palm (w here his w arm blood vessels are close to the surface of the skin) and the blue of his cool glasses.

This kind of imaging has been very important to scientists. These images of the Earth show ing ocean temperatures w ere taken from a satellite.



Infrared imaging has aided astronomers, too. These images show the constellation Orion as it is seen w ith visible light (left) and w ith infrared light (right).

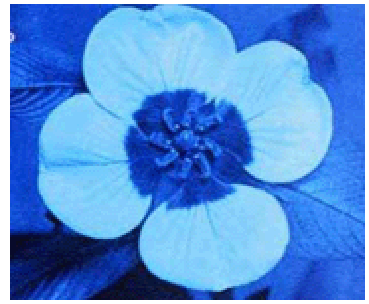


(Photo above: Courtesy of Infrared Information Processing Center, California Institute of Technology, Jet Propulsion Laboratory)

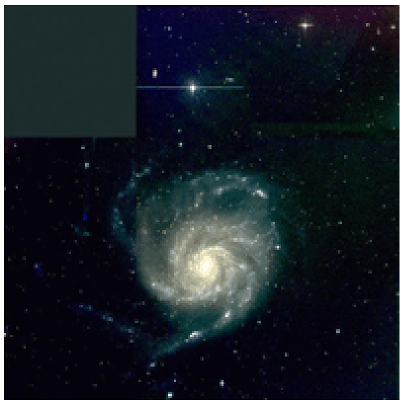
The yellow regions in the right image are hottest and show scientists the hot gasses around stellar nurseries. The clouds of red are relatively cooler interstellar gas and dust. Little of this information is available from visible light

Other animals (like bees) can "see" ultraviolet. A bee's view of flowers is remarkably different than ours. The following image shows a flower of a species of plant pollinated by bees.

In many ways this flower is unremarkable. However, a picture of the same flower taken with film sensitive to ultraviolet radiation looks very different. The pattern in ultraviolet guides a bee to pollen and nectar. (Photo's: Courtesy of Nectar Guides)

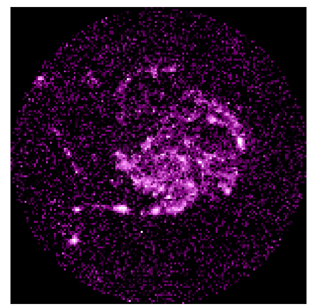


Detectors sensitive to ultraviolet light guide astronomers to new information. Peter Bunclark took this image of Galaxy M101 in visible light.

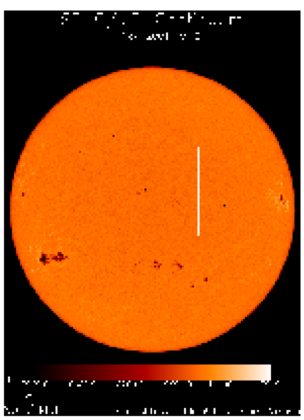


The image below is another view of Galaxy M101 taken by the Ultraviolet Imaging Telescope (UIT) onboard the Space Shuttle Endeavour. UIT is an instrument sensitive to ultraviolet light. The image has been computer processed so that the colors represent the intensity of ultraviolet light.

This shows mainly clouds of gas containing newly formed stars many times more massive than the sun, which glow strongly in ultraviolet light. The ultraviolet image shows astronomers much more about new star formation than the photograph taken in visible light. (Photo: courtesy of Ultraviolet Imaging Telescope)



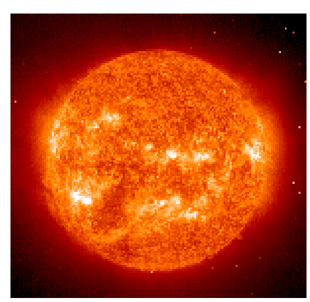
The Solar and Heliospheric Observatory (SOHO) is a project of international cooperation between the European Space Agency and NASA. Among its many scientific contributions, it enhances our knowledge by photographing the Sun in several wavelengths nearly at the same time. The following images were taken within 2 hours of each other. All colors are "false colors" chosen to help scientists know what wavelength is being viewed. The brightness corresponds to intensity of radiation.



The Michelson Doppler Imager (MDI) aboard SOHO took the image below. This image shows the Sun as it looks in the visible wavelengths. The scale at the bottom relates color to temperature.

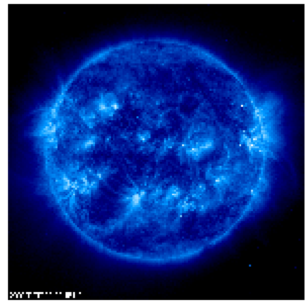
The dark areas are sunspots and the bright regions are faculae. These are regions of complex solar activity.

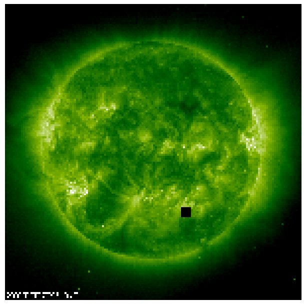
The Extreme Ultraviolet Imaging Telescope (EIT) took this image at an ultraviolet wavelength of 304Å.



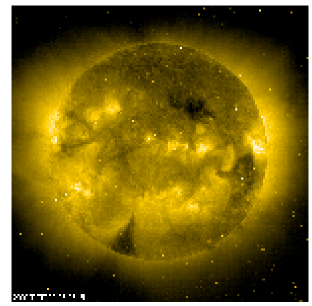
Scientists know that light emitted at this wavelength is predominantly emitted by helium that has lost one electron (ionized) at 60,000 to 80,000°C. Knowing the wavelength of light emitted tells the scientists something about the temperature, the chemistry and the layer of the Sun being viewed because helium can only exist in a particular state and temperature in specific locations. Notice that the regions of more intense radiation at 304Å correspond to regions where sunspots and faculae occur.

The following image was also taken by EIT at 171Å. Light emitted at this wavelength is predominantly emitted by iron that has lost 8 or 9 electrons that happens at 1,000,000°C. The features seen here are in the corona. Compare the areas of most intense radiation at 171Å with those at 304Å and the pictures taken by MDI.





The following image was taken by EIT at 195Å. Light emitted at this wavelength is predominantly emitted by iron that has lost 11 electrons at 1,500,000°C. The features seen here are in the corona. Compare these areas of most intense radiation with those in the other images.



The following image was taken by EIT at 284Å. Light emitted at this wavelength is predominantly emitted by iron that has lost 14 electrons at 2,000,000 to 2,500,000°C. The features seen here are in the corona. Compare these areas of most intense radiation with those in the other images.

The last three images show loop structures in the corona. The presence, structure and dynamics of these loops give scientists important insights into solar processes.

People are also familiar with the use of x-rays to allow us to "see" things that are not visible. But astronomers use x-rays far differently than doctors do. An x-ray of a broken bone does not show us the source of the x-ray. What we see in an x-ray picture shows different intensities of the x-rays coming through the object between the emitter and the film. William Conrad Roentgen discovered x-rays in 1895 and took this 'picture' of the hand of his wife, Bertha.

The bone of her hand and the metal ring blocked x-rays from the film. You can see a faint outline around the bone that is the skin and muscle. However, astronomers look directly at the source of x-rays and create images of the object emitting the x-ray. The Chandra X-ray image of Supernova 1987A shows an expanding shell of hot gas produced by the supernova explosion.

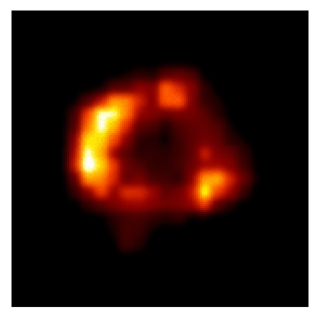
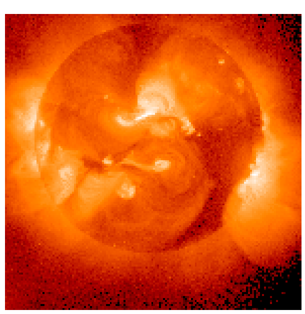


Photo: The colors represent different intensities of X-ray emission, with white being the brightest.

Recent optical observations of SN 1987A with the Hubble Space Telescope have revealed gradually brightening hot spots from a ring of matter that was ejected by the star thousands of years before it exploded. Chandra's X-ray image shows the cause for this brightening ring. A shock wave, traveling at a speed of 4,500 kilometers per second (10 million miles per hour), is smashing into portions of the optical ring. The gas in the expanding shell has a temperature of about 10 million degrees Celsius, and is visible only with an X-ray telescope.

Closer to home Yohkoh is looking at the Sun in X-ray. The image below is in a lower energy - or soft - x-ray.

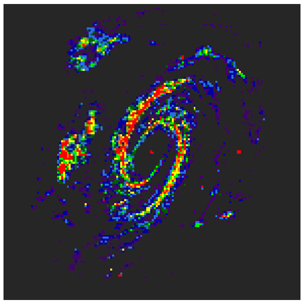
Photo: False color image courtesy of Yohkoh. Brightness indicates high intensity of x-ray. 2001/11719:52



The Soft X-ray Telescope on board the Yohkoh satellite was designed to study the hottest part of the Sun's atmosphere (the corona). Because the corona is so hot (2 million degrees Celsius) it is best studied by detecting the X-rays it emits. Scientists are able to compare x-ray data from Yohkoh to images from SOHO in ultraviolet and visible light. The image above was taken within a comparable time frame to the SOHO EIT images shown in the UV section of this page. Images taken at the same time in different wavelengths allow scientists to look at different parts of the Sun. They can then make connections between events in different parts of the Sun.

The Solar-B satellite, soon to be launched, will carry a coordinated set of instruments that will measure the Sun's magnetic field and simultaneously its ultraviolet and X-ray emissions. This data will improve our understanding of the Sun's variability and will contribute to a deeper understanding of the Sun's influence on life on Earth.

Electromagnetic radiation with wavelengths longer than infrared include radio waves and microwaves. We are most familiar with these types of radiation as carriers of radio or television signals or to heat our food most familiar with these types of radiation as carriers of radio or television signals or to heat our food. However, in 1931 scientists discovered that radio waves were coming from space and these radio waves were not carrying an extraterrestrial version of "I Love Lucy". Instead they were caused by electrons being accelerated by collisions or interactions with magnetic fields. Other radio wavelengths come from the behavior of molecules such as rotations or vibrations. Scientists are able to use radio emissions from space to determine the molecular structure and the surrounding environment of objects and clouds of dust and gas in space. One of the least understood of all radio sources are quasars (quasi-stellar radio source).



The following image shows Galaxy M81 taken at a wavelength that shows radio emissions from neutral hydrogen.

The most intense radiation is red and the least intense is blue. Scientists learn very important information about the structure and dynamics of clouds of dust and hydrogen around stars.

Scientists use an extremely powerful technique to study objects in space. They combine information from several widely different wavelengths. Click here for images of the Sun in all the different wavelengths.

Astronomers are also studying our own galaxy, the Milky Way. Our solar system lies about two-thirds of the way out away from the center of our galaxy. The Multiwavelength Milky Way shows our galaxy in 10 different wavelengths representing each major portion of the electromagnetic spectrum. Since the images show 360º we can see the entire Milky Way.

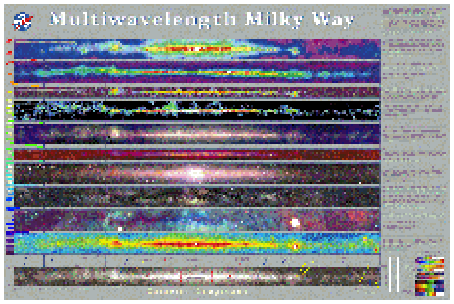


Photo Left: Courtesy of Multiwavelength Milky Way

It is well worth visiting The Multiwavelength Milky Way web site and seeing each part of the above poster in detail - or even ordering your own poster!

The development of instruments capable of extending our 'sight' into all wavelengths of the electromagnetic spectrum enables scientists to know so much more about the structure and dynamics of the universe. Multiwavelength Astronomy reveals the universe in all of its light.

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